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NBS BUILDING SCIENCE SERIES 100

Building To Resist The Effect Of Wind

VOLUME 5. Housing in Extreme Winds: Socio-economic and Architectural Considerations

ARTMENT OF COMMERCE • NATIONAL BUREAU OF STANDARDS

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Building To Resist The Effect Of Wind

In five volumes

VOLUME 5: Housing in Extreme Winds: Socio-economic and Architectural Considerations

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PREFACE

This report is one of a five volume series describing the results of a three and a half year research study to develop improved design criteria for low-rise buildings to better resist the effects of extreme winds. The project was sponsored by the Agency for International Development, Department of State. Volume 1 gives a background of the research activities, accomplishments, results, and reccommendations. Volume 2 presents a methodology to estimate design wind speeds and a guide to determine wind forces. In Volume 3, a guide for improved use of masonry fasteners and timber connectors is discussed. Volume 4 furnishes a methodology to estimate and forecast housing needs at a regional level.

This report presents information on the socio-economic aspects of low-income residential groups in developing nations subject to the effects of extreme winds.

The purpose of preparing this information is to complement technical material developed as part of the National Bureau of Standards high wind project, by identifying those cultural constraints which must be understood if recommended practices are to become acceptable and implemented.

The information contained in this report is the result of a broad-based search, review and analysis of literature sources supplemented by interviews with authorities in this field. Readily available source materials are listed in the Appendix. Much of that material is of a highly technical nature, and has been deliberately rephrased into simpler language in this report to make it accessible to decision-makers who will be called upon to implement the findings. Accordingly, illustrations, charts and tables have been simplified.

The report describes the circumstances in the Philippines, Jamaica, and Bangladesh, the same nations that were the subjects of study under the high wind project.

The author is indebted to the following individuals who kindly contributed useful information and suggestions: Noel J. Raufaste, Jr., Richard D. Marshall and S. George Fattal (National Bureau of Standards), John Edmondson and Paul Campbell (International Cooperative Housing Development Association), Wallace Campbell (Foundation for Cooperative Housing), Ignacio Armillas, Giovanni Carissimo, Evner Ergun, Alberto Gonzales-Gandolfi, Rafael Mora-Rubio, Mario Piche and Ludwig Van Essche (United Nations Center for Housing, Building and Planning).

ABSTRACT

Typical socio-economic conditions in the Philippines, Jamaica, and Bangladesh are identified. These conditions include strong respect for traditional materials and methods of house construction, and suspicion of innovative forms and approaches; a rising proportion of urban poor who live in squatter settlements; and a rising ratio of inhabitants whose incomes are at a level where they cannot afford housing of any kind. The importance of land from a social standpoint is stressed. The report reviews the sites and services concept whereby low income persons are provided a site equipped with basic utilities but must erect and maintain a house upon it. Recommendations include: placement of buildings to exploit terrain; adherence to good practices in the configurations of the main elements of a house (these are shown by means of simple drawings); use of cheap, strong and locally available materials.

Key words: Architectural design; housing; low income; low-rise buildings; sites and services; socio-economic; structural design; wind-resistant.

Cover: Corrugated-iron roofed houses dominate this hurricane-prone Caribbean village.

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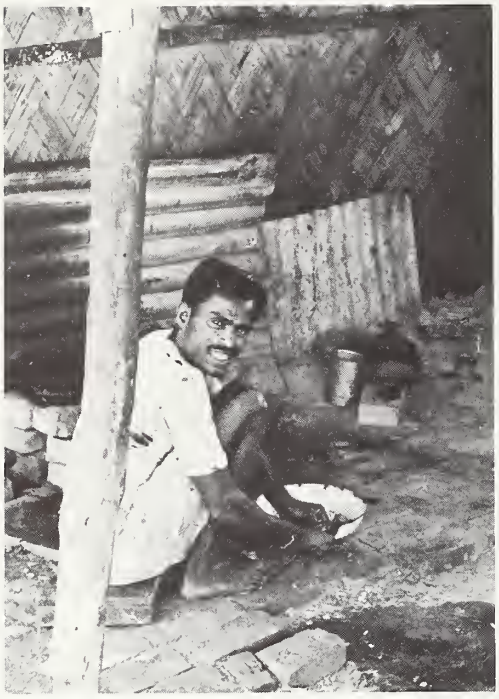
Facing Page: A scene typical of the three countries covered by this report, where the population is predominantly rural. In Jamaica, the ratio is 65 percent, in the Philippines 68 percent, and here in Bangladesh as high as 92 percent.

1. INTRODUCTION

This report is arranged in three major sections, followed by an appendix containing 23 references. The first section is organized to include information applicable across the board to the three nations where the principal study effort took place. Factors such as population density and income are discussed as they relate to housing quality, and the idea of uncontrolled settlements is reviewed in terms of its benefits and drawbacks. The same section also reviews housing characteristics (such as siting, design, and choice of construction technique and building materials) from the view point of how decisions affect the safety of houses under extreme wind conditions.

The second section reviews in greater detail the socio-economic characteristics of the three countries, and relates them to physical housing characteristics. By examining this relationship, the decision-maker is better able to improve the condition of building practices in each nation.

The third section evaluates the materials of the earlier sections and draws from them certain conclusions and recommendations. Committed decision-makers can expand these recommendations as they plan and carry out programs to improve the resistance of housing in extreme winds.



Facing Page: Blown-off roof and other building damage point to need for improved building practices to better resist extreme winds.

2. GENERAL DATA

2.1 SOCIO—ECONOMIC FACTORS

Cultural patterns, socio-economic restraints and technical expertise (or lack of it) can both enhance and be a severe barrier to innovation. Thus, understanding a nation's socio-economic profile, the characteristics of its housing and its administration, is a vital factor in improving current building practices.

The comparative socio-economic profiles shown on Table 1 tell much. All three countries in this study, Bangladesh, Jamaica and the Philippines have a high population density. It ranges from 122 persons per km^2 (317 per mi^2) in the Philippines to 525 per km^2 (1360 per mi^2) in Bangladesh, one of the highest in the world. Compare this with the U.S. density of 22, and that of the USSR, which has only 10 persons per km^2 (56 and 26 per mi^2) respectively.

In these developing countries there is strong movement from the countryside to the cities. As a result the major cities in all three have teeming squatter towns.

Table 1 A COMPARISON OF THE SOCIO-ECONOMIC CHARACTERISTICS OF THE PHILIPPINES, JAMAICA, AND BANGLADESH

	Philippines	Jamaica	Bangladesh
Population (million)	36.7 (1970)	2.0 (1972)	75.0 (1972)
Population increase (per cent per year)	3.0	1.5	2.6
Density (persons per km^2)	122	174	525
Squatter population increase (percent per year)	12.0	N.A.	N.A.
Percent of population in slums/squatter towns (percent)	5-6	N.A.	N.A.
Annual housing need (units)	100,000 (urban)	14,400	N.A.
	370,000 (rural)	N.A.	
Urban population (percent)	32.0	34.5	8.0
Rural population (percent)	68.0	65.5	92.0
Average household size (persons)	6.0	4.0	N.A.
Typical number of rooms in household	2.0 (Manila: 3)	1.0[1]	1.8[2]
Number of persons per room	2.7 (median)		3.2 (average)

Note: This table is designed to give general comparisons only, based on analysis of available information. Survey methods and frequency vary from one country to another.

[1] Percent one room dwellings: 42 percent (urban); 25 percent (rural) [2].

[2] Percent rural dwellings of one room: 53 percent [1].

In the Philippines, one person in 16 lives in squatter towns; the ratio as of 1970 was increasing at the rate of 12 percent a year. In Jamaica, squatter towns are growing (even though illegally). Information from Bangladesh is sparse, but Dacca and other major cities are known to have extensive squatter populations.

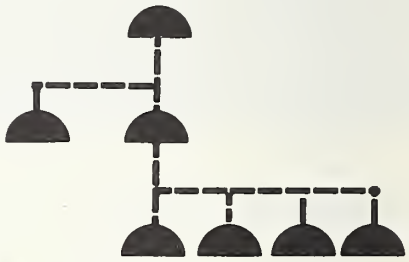
Over and above all this, the populations have been rising at a steady rate, from a low of one and a half percent per year in Jamaica (which has suffered emigration of its most skilled workers) to about two and a half percent year in Bangladesh and slightly over three percent in the Philippines. Furthermore, even though infant mortality has been dropping and lifespan rising through improved health care, citizens in these countries tend to live less long than in developed nations and this has led to a very high proportion of youngsters under 15 years.

Tradition, combined with lack of schools, has forced onto housing such functions as day care, education and play, for this high proportion of youngsters.

2.1.1 Population Factors

There are other ramifications to these population patterns. The economics of all three countries are highly labor intensive, so that children are seen as an economic asset. Family planning efforts designed to bring population more in line with food and other resources run up against this barrier, among others. This is especially true in rural areas where agriculture is the main source of income.

Several other factors stand out strongly. Foremost is the tremendous over crowding in available housing. In the Philippines, the average household size is six persons. The median number of persons in a room in the Philippines is 2.7. In Bangladesh, the average number is 3.2. It is traditional for several generations (so called *extended families*) to make up a single household.



A household often consists of several generations

To these factors one must add: shortage of funds, markets not large enough to stimulate economics of scale for prefabricated construction, undeveloped transportation and distribution systems, a shortage of skilled labor and, by and large, low standards of workmanship.

Furthermore, there is resistance by the various populations to certain construction materials and systems. A study carried out in Peru some years ago used igloo-shaped houses made of polyurethane. The houses were rejected because families were unhappy with the lack of corner areas where one could put things out of the way, predictably bad interior acoustics, and a lack of normally defined property lines in which to fence in animals. They were eventually abandoned.

Igloo shapes ignored needs and traditions of occupants

Most families cannot afford housing on the open market and in many cases not even housing subsidized by the government. The percent of those who cannot afford housing of any kind exceeds 65 percent in all the three nations that were analyzed. Consequently, the very poor must rely on government public housing programs (which are modest in all three countries) or build their own housing according to demonstrably unsound wind-resistant practices.

2.1.2 Uncontrolled Settlements

Uncontrolled settlements, a term which covers *bustees*, squatter towns, and transitional communities, have come in for sharp comment as to their socio-economic merit in developing countries.

The two sides of the coin are painted vividly in an article by Mildred Schmertz (see reference 10). Citing a survey of squatters carried out in six Philippine cities by Dr. Aprodicio Laquian, the article notes that the squatters "appear to appreciate their lives in the squatter community. The urban squatter's friends, relatives and neighbors are there, the communities are close to their places of work reducing transportation costs and time, and they have invested considerable time and money in their dwellings and community facilities and services. Of great significance to them, of course, is the fact that as illegal occupants they pay little or no rent or taxes and such amenities as they have are cheap. Laquian's figures support his thesis that relocation techniques will not work unless the new areas offer better conditions than those the migrant has already gained. . . ."

Yet, because "the non-taxpaying squatter is illegally based, and because his numbers overwhelm the city's public services, he does not have equal access with other citizens to roads, public transport, piped water and drains and must depend upon himself for such services. As a result, he has learned to expect little from the government and to view it cynically; on the other hand, the means exist by which his voice can be heard within the larger political and administrative arenas. The community organization to which he belongs has members with access to politicians and government officials at varying levels of hierarchy. His cynicism, therefore, is mitigated by his own experience of some degree of political effectiveness."

The other side of this situation is much more devastating.

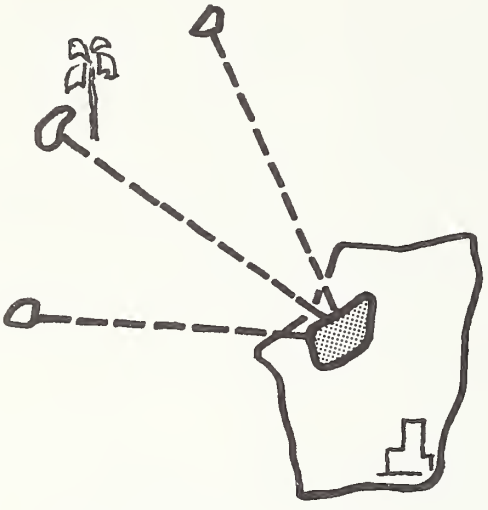
"Not all slum dwellers," the article goes on, "possess the characteristics of the migrants just described . . . Criminals . . . and the indolent are found in every slum. More common are those who are unemployed or underemployed and have become adjusted to poverty, or for whom, . . . it is simply inescapable."

"In the world's worst slums such as those of India and Africa, many people are slowly starving. They are apathetic, hostile, and suspicious. . . ."

Uncontrolled settlements: pros and cons (see reference 23).

1. They provide migrants with housing at rents they can afford.
2. They serve as a reception center for migrants, helping them to adapt to urban life.
3. Within their own society they are a source of jobs in small-scale and marginal enterprises.
4. They provide accommodation at a reasonable distance from sources of jobs in the adjoining town or city.
5. The communal organizations provide support during unemployment and other difficult times. (A study by a Presidential Council on the Squatters of Manila, the Philippines, found, in a squatter community of 2,625 families, 29 organizations, with 65 percent of family heads interviewed belonging to at least one organization.)
6. They encourage (and reward) small-scale private enterprise in the field of squatter housing.
7. In many cases, they provide their own security system of a caliber that Government would find very costly to furnish.
8. Some planning professionals question the

merits of uncontrolled settlements, due to the public health, educational, family health care, circulation and other problems which these settlements find hard to solve. The absence of "sites and services" aggravates these conditions.



Squatter towns serve as reception centers for migrants, and help them adapt to urban life.

Four fallacies: Four fallacies of thought have arisen around the squatter town problem:

1. The more squatter settlements are improved, the more migrants are attracted to them.

   Response: Social and economic stimuli will continue to attract migrants to urban areas no matter what the living conditions.

2. Improvements in rural areas can significantly reduce migration to urban areas (see reference 14).

   Response: Without urbanization and industrialization, there is little prospect of rural development. The real question is: how is it possible to prevent the exchange of rural poverty for urban misery?

3. Decentralization of urban growth will reduce problems of urbanization (see reference 14).

   Response: Large scale capital investment in a number of rural areas designated as growth centers, may tend to attract migrants to relatively small towns which, at least in the short and medium term, would [lack] the financial and staff resources for providing community services, and otherwise dealing with a rapidly growing population.

4. Squatter settlements are homes largely for rural and uneducated groups.

   Response: Squatter settlements vary widely. Residents of some are close to their rural backgrounds. In others, there is a notable proportion of professionals, such as engineers and doctors.

The occupations of Squatter community residents vary widely

2.1.3 Sites and Services

A policy that is becoming more and more accepted is to improve squatter settlements by providing *sites and services*. Land, water supply, electric power and waste disposal are provided. Unsteady buildings are replaced by better structures with appropriate help as the settlement becomes more established. This way, self-help is stimulated.

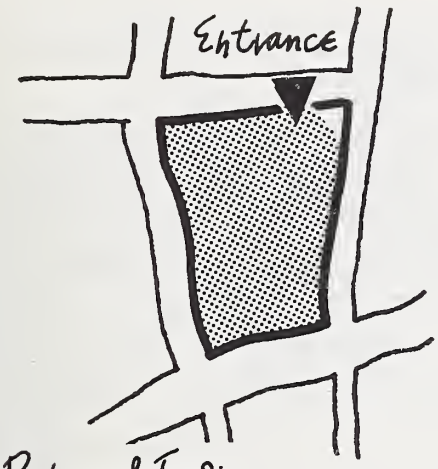
A key move from a public planning standpoint is to incorporate the sites-and-services concept into municipal or regional zoning programs.

Types of sites and services: Following are four forms of sites and services (see reference 19).

1. Subdivide land alone—only an unimproved building lot is provided.
2. Subdivide land and install basic public utilities and some community facilities.
3. Subdivide land and add a full complement of public utilities and community facilities.
4. Install a combination of public utilities and community facilities in existing residential areas.

An interesting variation on the above are the *poles* of India. An entire downtown block owned by the Government is leased to a private individual or company, which then rents space to transient occupants. The block is entered only through a guarded gate, with rent collected weekly. Temporary structures inside the walls serve newly arrived migrants who are close to work and temporary job sources, and have the opportunity of acquiring more permanent jobs and housing.

Hierarchy of public utility services: As the sites and services concept evolved, a hierarchy has emerged among the public utility services a government may provide.



Poles of India:
temporary structures inside walls of downtown block owned by government are leased to transient migrants

In the top category are water supply and waste removal, since lack of purity in the one and improper location and design of the other are the primary causes of disease and mortality in squatter settlements.

Water and waste lines, if linked to a sanitary core, constitute a minimum standard.

Waste and water lines, with sanitary core if possible, are a minimum standard

In the next category are utilities such as electricity and public lighting, sidewalks and paved roads, gas and telephones.

Public utilities make up one of three components of the sites and services concept. The other two are community facilities (or access to them) and the land itself.

The importance of land: From a public health standpoint, the need for proper water and sanitary systems is uppermost. From a social standpoint, it is the security of land occupancy or ownership. Most families, given technical assistance, will find a way to erect a dwelling, so long as they can count on security of land.

To lower the cost of land for the occupant, a variety of arrangements is possible. An approach tried in Jamaica offers a 40 year leasehold on land at a modest rental; this is renewable for 40 years more. The lessee is responsible for erecting housing and paying for utilities. The only subsidy is in the form of technical assistance.

The importance of jobs: Work, its presence and access to it, is a major force in the life of the squatter community. This concept was the central theme of a design proposal that won for Ian Athfield of New Zealand the first prize in an international competition to design a master plan and *new town* on a site called Dagat-Dagatan—for eventual resettlement of 17,000 families living nearby on Manila's abject Tondo Foreshore (see reference 10).

Athfield's scheme makes the workplace the major controlling element of the design. It would be the first part of each neighborhood unit or *barangay* to be built, initially along its periphery. An area within each such a working periphery would control the supply, manufacture and use of building materials for erecting housing. Space within the periphery would also be leased to private light industry to create further jobs.

2.1.4 User Requirements

Research into user requirements on low cost housing can help evolve designs that are both technically adequate and also meet socio-economic needs. Clearly, since most current designs for low-cost housing do not meet proper wind-resistance criteria, new designs, quite possibly using unfamiliar building materials and methods, will have to be used. As there are no hard data on user acceptance of new designs, this information on user acceptance must be sought out.

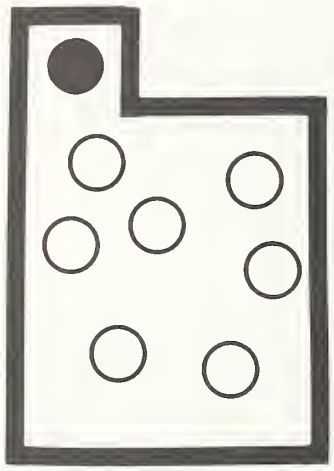
Dr. Tarja Cronberg (see reference 15), used these sources of information: statistics of the country's population (death rate, size of families, average income, etc.); interviews with local builders, architects, and construction workers; and observation. She divides the information into two classes: *user characteristics*, and *user activities*.

Under user characteristics, she identifies the users' typical physiological and psychological characteristics, plus such socio-economic characteristics as family size and structure, mobility, identification with a particular ethnic, religious or geographic

group, and educational background.

Under user activities, Dr. Cronberg identifies nine categories:

- Sleeping
- Food preparation
- Storage
- Personal sanitation
- Work
- Recreation/play
- Social (receiving of guests, etc.)
- Identification/participation
- Learning and orientation



Need for personal space and privacy in crowded houses is one issue that requires further research

She concludes that more information is needed in four areas:

- Health standards in existing environments.
- Need for personal space and privacy in overcrowded housing.
- Social activities in the neighborhood and community.
- Activities of specific groups such as children.

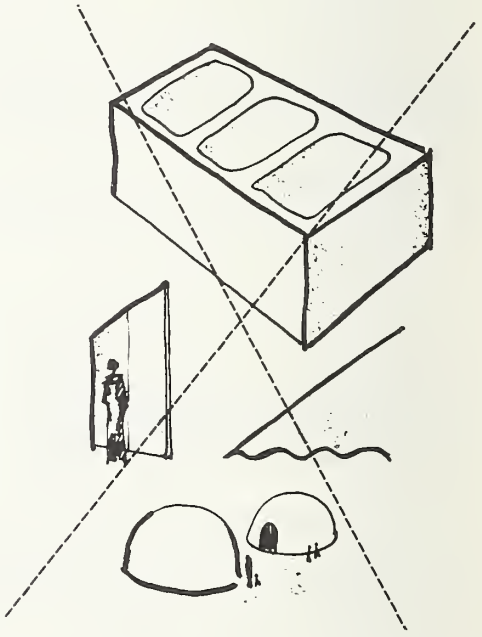
This determination, to be done with the aid of local experts, is clearly important in arriving at a clear, objective set of criteria of how families in a given milieu are likely to respond to innovative, wind-resistant design that is new or unfamiliar.

The Cronberg study also indicates that innovative housing designs and new materials are widely accepted in the Philippines, even by low income owners. This is true especially where the owner is able to make small individual changes on his house after he moves in. Most practicing architects and engineers in the country generally accept new materials which have the needed properties and if the cost is reasonable.

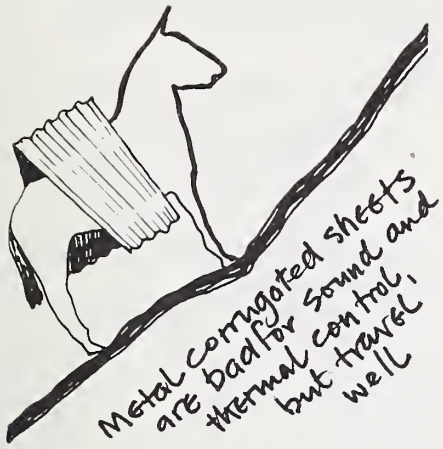
The opposite has been the experience in Peru. Peru is not a part of this report, but is a useful object of study nevertheless. New construction materials usually are initially rejected in Peru; only a few have survived this reaction and managed to keep a place in the market (see reference 15). Examples of building products that have been rejected include:

- A hollow block based on a Swiss patent and made up of mineralized vegetable fibers encased in cement.
- A panel-sized product made of expanded gypsum.
- Corrugated sheets of glass fiber and polyvinyl chloride (PVC); plastic bathtubs and basins.
- Sprayed polyurethane igloos developed in Germany for use after earthquakes.

New construction materials are rejected, at least at the start



The few construction materials (other than indigenous materials) that are broadly accepted are corrugated sheets of galvanized steel and asbestos cement. The former, despite poor thermal and acoustical properties, are popular because they are strong, are light weight, and can be easily and cheaply transported on the backs of mules. The latter, though superior in thermal and acoustic terms, are quite fragile, the resulting higher breakage also drives up costs, and are carcinogenic.



2.1.5 Attitudes to prefabrication

Another Peruvian study with lessons for other developing countries is a 1962 survey of public attitudes towards prefabricated housing. It was carried out by students at the Architecture Department of Peru's National University of Engineering.

Consumer interest was found to be low because prefabricated houses cost only a little less than site-built brick and concrete houses and a good deal more than adobe houses; they looked too uniform; and the public did not appreciate the savings inherent in the shorter construction time. As for builders, they found that a restricted market led to high sales/costs; financing was difficult; and complex transportation sharply raised construction costs outside the immediate area of Lima.

Prefabricated look-alikes slow down acceptance

2.1.6 Housing economics

Housing approaches in developing countries have been criticized on two grounds. First, housing deficits are computed without taking into account the values or preferences of those to be housed. Secondly, the traditional solutions to housing deficits have turned out to be well beyond current capital investment rates. Even in countries that anticipate a high rate of economic growth, the competing demands of agriculture, industry, and other programs reduce the funds available for housing to a level far below needs (see reference 15).

In the Philippines, for example, demand for new dwellings would require a capital investment about 5.7 percent of the gross national product; in fact, in 1967 only 2.8 percent was so invested.

In the Philippines, doubling capital investment would fill housing demand

Yet the *sites and services* solution referred to earlier has been found desirable, especially in the Philippines, where self help (known as *bayanihan*) is widely accepted in the building of dwellings. It is discussed in greater detail later in this report.

2.2 HOUSING CHARACTERISTICS

Four ingredients of housing are discussed. These are: siting, design, construction methods, and materials.

2.2.1 Siting

Little regard has been given to the placement of houses in relation to danger from winds. Good site location or orientation linked to local terrain and natural cover can be, but usually has not been, determined from historical wind data. This data provides the frequency velocity and direction of the prevailing winds, especially in their extreme form. Hence, windstorm damage can be reduced by placing buildings so they are protected by hills, stands of trees and other natural elements.

The concept of landscape and terrain as a factor in wind resistant design has been formally established in the *British Code of Basic Data for the Design of Buildings.*

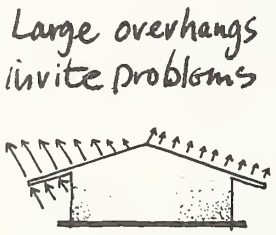
In introducing the concept of the topography factor, that is, of classifying varying degrees of ground

roughness as a wind design determinant, the code recognizes four categouries of terrain:

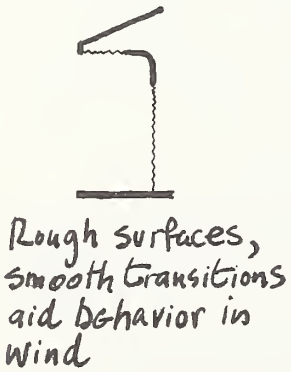
- Long stretches of open, level or near level, country with no shelter;
- Flat or undulating country with obstructions, such as hedges, scattered windbreaks of trees and occasional buildings;
- Surfaces with many large obstructions, such as well wooded parkland, small towns and the suburbs of large cities;
- Built up areas with a general roof height of above 25 m (82 ft).

2.2.2 Design

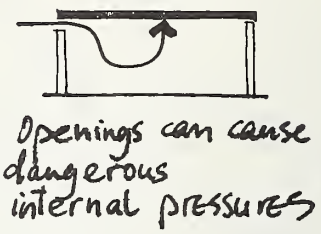
It is possible to make buildings more wind resistant by improving connection details, by learning more about the effects of wind loading on buildings, and by avoiding certain shapes or groupings of buildings so as not to cause undesirable aerodynamic effects. To those ends, theoretical as well as experimental wind model research is currently being conducted.



Certain design elements can reduce wind resistance. Sharp edges, low-pitched roofs, large overhangs and improper grouping of buildings will cause problems. The aerodynamic behavior of buildings can be improved by providing rough surfaces or ribs on the exteriors of walls. Grass roofs have allegedly served to relieve pressures, as have smooth transitions between building surfaces (see reference 15).



Unfortunately, the internal pressures developed in buildings with openings are usually not considered in design. Roof failures have been caused by wind which penetrated the structure and pressed up on the roof from beneath.



Certain configurations (such as cylinders, and igloo-type structures), are far more stable than box-like structures, but in the few places where they have been tried the cultural attitudes of the population caused them to be abandoned.

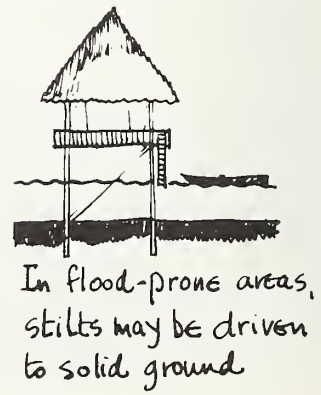
In Bangladesh, various building designs were tried using materials and shapes new to the country. These are integrated roof and wall elements, made up of units consisting of polyester resin and jute. They have performed well in wind but their final social acceptance is still unknown.

2.2.3 Construction Technique

In developing countries, it is often hard to separate design from construction. By and large, typical characteristics can be summarized as follows:

Characteristics—foundations, walls and roofs:

1. Foundations. Load transmission to soil becomes less critical since low-rise dwellings of one or two stories do not generate a high dead load. Where flooding is not common, rectangular footings of plain or reinforced concrete or gravel are used. In flood-prone areas houses may be built on stilts (e.g. bamboo) driven into the ground to the appropriate depth. Mat footings are sometimes used on unfavorable soil.

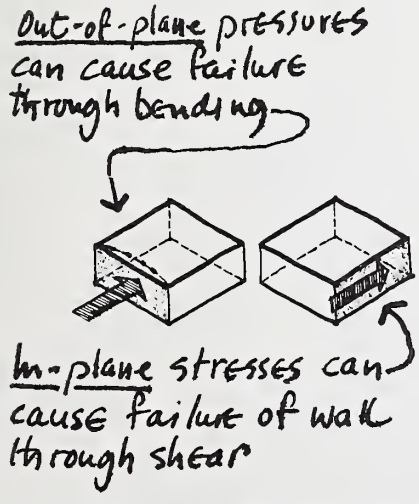


Mat footings spread loads over a greater area

2. Walls. Walls are either structural or non-structural. When non-structural, they merely serve as an in-fill for a frame and their contribution to the overall structural resistance of a building to wind pressure should be minimal.

   Structural walls of wood, concrete, burnt clay or soil-cement composition are the most common in low-cost housing construction. Walls are either monolithic or small unit masonry type, where units are laid in staggered courses, usually in beds of mortar. Clay brick and tile, adobe brick and concrete block are the most common masonry units. Quality control in making these units, as well as the mixing of the masonry mortar bed, can make or break the structural strength of the total wall.

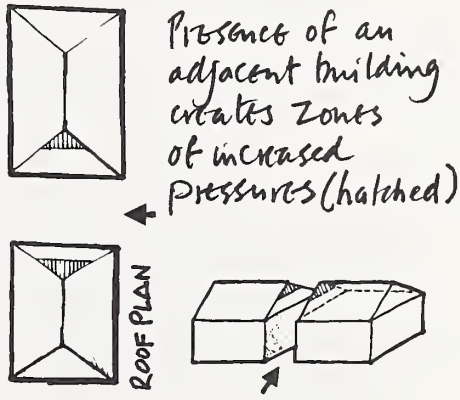
   Wind stresses on walls are either out-of-plane bending or in-plane stresses. Out-of-plane pressures (when wind acts directly at right angles to a wall) cause deflection and eventually failure. Tornadoes common in Bangladesh have pressure drops so strong and sudden as to actually pull walls outwards.



   In-plane stresses are developed in walls which act as shear-resisting elements within the building, the plane being parallel to the wind direction.

   Moreover, incorrectly planned wall openings may be critical, especially at corners. In any case, conditions where two walls intersect or between walls and foundation or walls and roof, require special design due to the high stresses at those joints.

3. Roofs. Roof pitch is an important design element for good wind resistance. The magnitude of positive or negative wing pressures on roof surfaces is directly related to roof pitch. Wind affects roofs in two ways, direct and indirect.

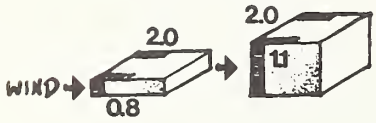


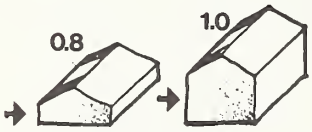
   Direct local effects are made up of high positive or negative pressures over local areas of the roofs. This may lead to damage to roofing—whether shingles, tiles, corrugated sheets, etc. Overhangs, common for sun protection, are especially liable to wind damage, as they undergo positive pressure from below and suction from above.

   Indirect effects occur when wind loads are transferred to lateral walls, causing stresses. If this mix of pressures on the roof is strong enough, the capacity of the connections will be exceeded and the roof will be lifted off. This brings additional danger since every roof has a structural role as a horizontal diaphragm. This diaphragm behavior of the roof transmits windloads from the front to the side walls. If a roof is blown off, both frontal and lateral walls may collapse due to loss of such diaphragm stiffening.

Builders sometimes use an ingenious network of cocoanut matting and cables to anchor roof down.

Flat roofs (especially with overhangs) are more subject to wind damage than roofs with a steeper pitch.





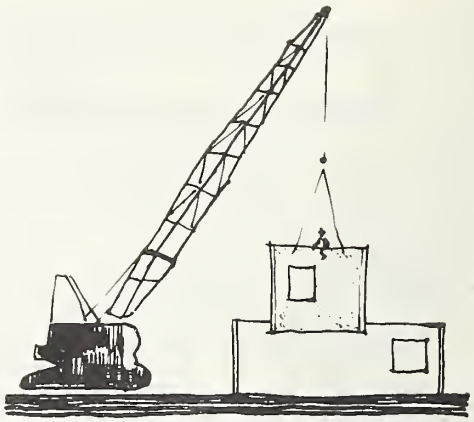
"Shaded" areas are zones of maximum wind pressure. Numbers are a measure of relative intensity. Note effects of height and roof pitch.

Prefabrication: Any method that will produce housing more effectively must, at least in its first phase, make the best use of available local labor.

In the Philippines, few companies make prefabricated components; those that do are private firms producing wall panels and roof trusses, and a government firm which makes lightweight concrete panels. Filipino builders are said to recognize the savings which prefabrication offers, and feel they can make it work. Their problems at present are lack of adequate financing and too small a volume.

In Bangladesh, reinforced concrete shell roofs in the shape of a hyperbolic paraboloid have been used, using 25 mm (1 in) pre-cast reinforced concrete elements, with concrete connections made on site.

In Jamaica, the most common form of industrialized construction consists of large precast concrete panel systems. Wall and roof panels are lifted and assembled by crane. Other forms of prefabrication in Jamaica use precast posts combined with precast concrete or timber beams, with concrete infill panels between posts.



Two technically creative projects are underway in the Kingston area. The Portmore development in St. Catherine was planned to produce 30,000 houses and one-third of these were completed by late 1975. The cast concrete construction system consists of large concrete panels, cast in fiber-glass molds, erected by the *vacuum lift* process and interconnected by welded anchor plates. Structural elements vary from solid concrete to ribbed panels, with a minimum panel thickness of 38-mm (1-1/2 in). The developers (and builders) of the system, West Indies Home Contractors Ltd., claim to be able to produce 15 units per day (five units of three different houses), from one precasting yard and factory.

The other project consists of houses in Kingston designed by U.S. architects Baker/Grinnell as proposed for government-sponsored low-income housing. The system (a prototype has been built on site), consists of gypsum and bagasse panels—a locally available particle board made of sugar cane fibers—and a treated paper honeycomb core. The panels are produced on site by a lightweight portable machine which has its own power supply. When it is operating at full capacity, the developers claim the system can erect up to 50 houses per week from a single fabricating unit.

The structure of this house has been reviewed by the New York structural engineer Paul Weidlinger, who said the house would resist winds of 53 m/s (120 mph) under extreme conditions of pressure and suction, assuming open windows. The earthquake resistance is for a zone three shock (Jamaica is in zone two).

2.2.4 Materials

Following are common materials used in the three nations:

Soil: Natural earth is about the most common material used. Sun dried adobe bricks have been the basic masonry units for low-cost housing. These bricks are often untreated against penetration by water.

More recently adobe brick has been stabilized by the addition of asphalt. This boosts the durability and water-repellant properties and is a major breakthrough. The social image however, of adobe, stabilized or not, is still not high.

Wood: Wood, while popular, easy to handle, versatile and strong in tension, is not available everywhere. It is useful as a framing material. When not available in milled, dimensioned form, it is replaced by non-dimensioned lumber—as cane, bamboo, palms and thatch for structural enclosure and roofing pruposes. Cane, bamboo or split wood are often used to reinforce adobe masonry. Major draw backs are moisture, fire and insect infestation. Chemical preservatives which are produced in developing countries can prevent this kind of danger and deterioration. Also, chipboard products are used for walls and ceilings.

Concrete: Where sand, cement, water and various additives are plentiful, concrete is a logical and widespread local building material. Weak in tension, it can be reinforced by a local material such as bamboo as well as by costlier imported steels and fiber-glass.

Concrete reinforced with a wire mesh and known as ferro-cement has been used with very little supervision in some countries, and the needed materials are cheap and usually readily available. A strong case has been made for every developing nation to invest in a

cement plant since the raw materials can be cheaply furnished using local labor. The rest of the production process similarly can make do with unskilled labor at most stages.

Brick and concrete block masonry: Brick and concrete block masonry are common.

Steel: As a capital-intensive material, steel is rarer. Its most common use is as a roofing material (in the form of corrugated sheets of galvanized steel or aluminum), and to a small extent as connectors for bolting and anchoring the various structural elements.

Plastics: Plastics are a highly adaptable material. Depending on the choice of components, they can be tailor-made to adapt to most structural and enclosure needs of housing. Not enough is known about the weathering properties of plastics in outdoor use (as compared to traditional materials), especially in tropical areas such as those in this study. Use is most advanced in the Philippines, which also is one of the chief plastics producing countries in the Far East. They use native as well as imported raw materials and processing machinery. Several important tests underway in Bangladesh are described later in this report.

Still, plastics are resisted as a new and unfamiliar material. Solid-seeming and demonstrably durable materials are preferred. Plastics are likely to be more widely accepted in the future as they penetrate the private, for-profit housing market and non-housing uses such as clinics and schools. They can then be observed and their performance seen by those who presently must rely on housing provided by their governments or through their own labors.

Indigenous fibers: Indigenous fibers, such as palm leaves, coconut husks and peanut shells have served as filler materials in spaces between structural supports or between roof rafters; and grasses such as jute and hemp can be used as reinforcement for concrete or adobe masonry.

2.3 PRIORITIES

A constant dilemma among policy makers in developing countries is the tug-of-war between food and building materials for use of precious foreign exchange. In most cases food wins out, as in Bangladesh, placing increased pressure on development of a domestic materials producing capacity.

Facing Page: Houses such as this are flimsy but could be made to better resist high winds if adequately braced and securely anchored to the ground.

3. REVIEW BY COUNTRY

The preceding material describes housing in the Philippines, Jamaica and Bangladesh in terms of their socio-economic profile and physical housing characteristics. In the material that follows, there will be separate, detailed descriptions of conditions in each of these three countries. In this sense, this section should be seen as an extension of the previous one.

3.1 THE PHILIPPINES

The Philippines have the highest frequency of tropical storms (wind greater than 18 m/s) in the world. Average annual frequency is 20.

Filipinos have always depended on water (whether fresh or salt) for food, transportation and for watering their fields. This is still the pattern in rural areas. This attachment to low land and water logged areas led to a unique type of dwelling, with a raised floor on stilts. Communal activities centered around the houses of the village elders, who also were religious and judicial officials. This organization has today been formalized into the barrio, which is the lowest political unit of government.

3.1.1 The Filipino Family and Their Housing Needs

The family is the strongest unit of society. Kinship is often extended as far as the third or fourth cousins. Families with at least three generations living in a single house are common. Extended families exist not only in the country but also in cities. Their percentage in low income areas around Manila reaches 55 percent (family size ranges from seven to 11 in these cases, with at least 18 percent made up of nine members). In times of crises, family members are expected to share board and shelter with less fortunate relatives, especially parents in old age and widowed relatives with children. The family acts as the economic unit in rural and urban areas. Children are seen as economic assets. A large family is regarded as a means to social security.

3.1.2 The Community

Ranking cities in the Philippines have between 10 and 45 percent of their populations in slums or in squatter areas; the national average is five to six percent. Filipino squatters are said not to be shiftless people, but well motivated and resourceful.

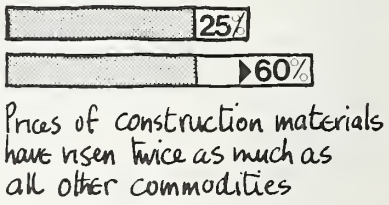
A study made by Jaime Laya, Remedios Balbin and Romulo Neri of the Agno-Leveriza squatters area of Manila (see reference 7, part H) paints a grim physical picture. Eight hundred dwellings are crammed into two city blocks behind a prosperous seeming facade of solid apartments and houses. Most structures are of one or two rooms, without running water or toilet. About 12 percent of surveyed heads of household were unemployed.

Yet the study team noted little active discontent; rather, they found an attitude of initiative, of moving on by one's own effort and enterprise. Education level was relatively high (7.1 years of schooling on average for heads of household, more than needed for the jobs they hold), and income level varied widely, from destitute to families with a refrigerator, television set and telephone service.

Another study, by Mary R. Holnsteiner (see reference 7, part I) confirmed a sense of excitement among squatter families after they left a dull rural existence and moved towards economic opportunity in the city. One recommendation of this study, which looked into options for relocating Manila squatters, was to weigh with care any plan for moving families off to a site too remote from urban job opportunities.

3.1.3 The Need for Housing

The estimated annual need for urban housing alone averages 100,000 units—to accommodate population increase, new family formations and replacement of squatter dwellings. The cost of land is high and this has a direct effect on the high cost of adequate housing. In addition, wholesale and consumer product prices rose sharply between 1970 and 1973. The average increase for all commodities was 25 percent; for most construction materials the figure was 40 to 60 percent. On the other hand, downward pressure on the cost of materials for conventional construction is exerted by the low cost of delivering materials, since production is spread throughout the country.



3.1.4 Economic Aspects

The Filipino economy as measured by its Gross National Product (GNP) rose at an average annual rate of 6.6 percent during 1968 to 1973. Investment in housing rose from 2.8 percent of GNP in 1967 to 4.0 percent in the early 1970's. But to meet the country's total housing need of some 470,000 units per year, an allocation of 5.7 percent is required. Average per capita income ($130 in 1970, U.S. dollar equivalent) also rose, and is expected to double in the next 10 to 15 years.

Only 12 percent of the population (with annual family income over $1490—U.S. dollar equivalent) can afford housing on the open market.(See reference 7, part A).

Twenty-three percent can afford to own a house if offered long term cheap financing with modest land, development and construction cost ($596 to $1489 annual income range). The rest cannot afford shelter at any cost.

The amount a family can afford for housing varies chiefly with its income and location along with other lesser factors. For example, according to a study by Sixto L. Roxas III (see reference 7, part E), a family with an annual income of $300 can afford a house 1.3 times its income, or $390. At an annual income of $450, it can afford a house of 1.8 times its income, or $805. This sets certain numerical limits on the cost of low income housing.

In addition, income varies in different regions of the country, with families in urban areas outside of Manila having a higher pattern of income than Manila and rural areas (see reference 7, part E). All these economic aspects are important in determining realistic parameters for the design and construction of low-cost, wind-resistant housing.

3.1.5 Housing Characteristics

Key housing characteristics are shown in Table 2. Note the sharp differences between statistics for metropolitan Manila and for the Philippines as a whole. Statistics are based on surveys by the Bureau of the Census and Statistics and by the Population Institute National Demographic Survey. They give little idea of the actual condition of dwellings themselves.

Table 2: KEY HOUSING CHARACTERISTICS IN THE PHILIPPINES[3]

a. TYPE OF DWELLING UNITS BY STRUCTURE (PERCENT)

Type	Metro Manila	Philippines
Single Family Dwelling	57.6	78.9
Duplex	5.5	4.1
Accessoria	15.1	2.3
Apartment	8.1	1.1
Barong-Barong (shack)	4.4	5.4
Commercial Building	1.0	1.3
Other or No Response	8.3	6.9
Total	100.0	100.0

b. NUMBER OF ROOMS IN HOUSEHOLD EXCLUDING BATHROOM AND TOILET (PERCENT)

Type	Metro Manila	Philippines
One Room	11.3	14.1
Two Rooms	22.5	28.4
Three Rooms	23.1	25.7
Four Rooms	19.8	14.3
Five Rooms	8.0	6.5
Six Rooms	3.8	2.6
Seven Rooms	1.3	0.8
Eight or More Rooms	1.6	0.6
No Response	8.7	7.0
Total	100.1[4]	100.0

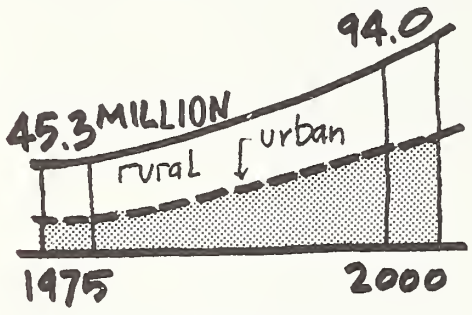
c. DENSITY (PERSONS PER ROOM) WITHIN HOUSEHOLD (PERCENT)

Type	Metro Manila	Philippines
Less than one person per room	5.1	6.1
1.0 to 1.9 persons per room	27.8	27.4
2.0 to 2.9 persons per room	26.5	27.4
3.0 to 3.9 persons per room	14.1	13.7
4.0 to 4.9 persons per room	7.7	7.7
5.0 to 5.9 persons per room	4.2	3.7
6.0 to 6.9 persons per room	1.5	2.8
7.0 to 7.9 persons per room	1.8	1.7
8 or more persons per room	2.7	4.5
No Response	8.7	7.0
Total	100.1[4]	100.0

[3]See reference 13.
[4]Rounding error.

3.1.6 Population trends

Table 3 shows the results for the Philippines of a world-wide survey conducted by the United Nations to identify population trends. The information is updated through June 1974; population figures are broken down by urban and rural, and indicate projected rates of increase. Information for five-year periods from 1975 to 2000 are given. The trend shows increasing urbanization although the rate of increase is shown to be decreasing.



Population will more than double in one generation. By 2000, half the population will be urban

3.2 JAMAICA

3.2.1 Socio-Economic Aspects

Virtually all Jamaican housing built by the private sector today falls outside the definition of low-income housing. To qualify, the cost of house plus a developed site must be under $5,500 (U.S.). Whereas 33 to 42 m^2 (350 to 450 ft^2) is a minimum standard for social housing in developing countries, a more attainable standard for people with no fixed income brings this closer to 19 m^2 (200 ft^2) in Jamaica. In such cases, provision is usually made for the owner to extend the house at some future date.

Traditionally, urban low-income housing has been high-density apartments—terrace houses or small groups of houses closely clustered around a communal yard.

Detached houses have been more typical of middle income groups, and have become the goal of upwardly-mobile low-income groups. Over the past 10 to 15 years this has caused developers of low-cost housing, in order to keep prices down, to erect groupings of closely spaced, single-story detached units on tiny lots.

Oddly enough, a middle-income trend back to apartment living is seen as encouraging a similar trend among low-income groups, which may now be more likely to accept multi-story and terraced housing,

Table 3: POPULATION TRENDS IN THE PHILIPPINES, JAMAICA AND BANGLADESH 1975-2000[5]

	Population (in thousands)				Annual Rate of Increase Preceding 5 years (Percent)			
	Urban	Rural	Total	Percent Urban	Urban	Rural	Total	Urban Rural Difference
a. PHILIPPINES								
1975	15837	29468	45305	34.96	4.51	2.70	3.32	1.81
1980	19936	33594	53530	37.24	4.60	2.62	3.34	1.98
1990	31272	42132	73404	42.60	4.39	2.07	3.03	2.32
2000	46068	47956	94024	49.00	3.66	0.99	2.25	2.66
b. JAMAICA								
1975	830	1199	2029	40.89	3.51	0.22	1.50	3.29
1980	973	1199	2172	44.79	3.19	-0.00	1.36	3.19
1990	1291	1173	2464	52.38	2.72	-0.27	1.24	2.99
2000	1619	1107	2726	59.39	2.06	-0.74	0.88	2.80
c. BANGLADESH								
1975	5296	73616	78912	6.71	4.87	2.78	2.92	2.09
1980	6850	85243	92093	7.44	5.14	2.93	3.09	2.21
1990	11657	114235	125892	9.26	5.36	2.91	3.12	2.45
2000	19395	146117	165512	11.72	4.97	2.28	2.57	2.69

[5]Courtesy United Nations.

with its more efficient use of limited land and resources.

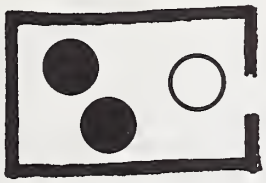
A useful if not totally representative picture emerges from a survey of housing conditions in the Delacree Pen district of Kingston, Jamaica. Delacree Pen is the site of an urban renewal project. The survey disclosed that of the 4,935 households, 68 percent lived in one room; 18 percent in two rooms and eight percent in three rooms. The most common household size was from five to seven (24 percent); 37 percent were of one or two persons, and 11 percent had eight or more members.

A notable feature of the Delacree Park urban housing project (located in the Delacree Pen District) is its character as a housing cooperative. Such a cooperative, established with government, World Bank or other subsidies, is a useful vehicle for erecting housing, in the construction and maintenance of which the occupants have a strong social and economic stake.

Eventually 350 units will be built in Delacree, in the form of wind-resistant two story garden apartments arranged in clusters of six. The program has been well-received—both in its social and its economic context.

One difficulty has been adherence to occupancy standards—a common problem in developing countries. Delacree Park units, which have a living room and two bedrooms, may house up to six people, according to government standards of two to a room. In practice, families sometimes have as many as seven children; consequently the government, knowing it cannot afford to subsidize such supplemental spaces, will permit its occupancy standard to be exceeded by up to 50 percent.

By and large, cooperatives are now an accepted method for erecting housing in Jamaica. The Jamaican Ministry of Housing has created a Division of Cooperatives and Condominia to coordinate this effort.



Occupancy of 50% over standard is sometimes condoned

3.2.2 Housing Characteristics (See Table 4)

Jamaicans generally prefer concrete houses and do not like houses made of light-weight materials, unless they are forced to live in one for financial reasons (see reference 1). Almost half of Jamaican housing is made of concrete. Until recently there has been a bias against *precast* concrete houses (especially those of thin cross-section) but this is disappearing.

Table 4: KEY HOUSING CHARACTERISTICS IN JAMAICA[6]

a. DISTRIBUTION OF DWELLINGS BY TYPE OF TENURE (PERCENT)

Type of Tenure	Total	Urban	Rural
Owned	52.4	29.7	70.8
Leased	2.5	3.9	1.4
Rented	36.5	59.9	17.6
Rent-free	7.9	5.8	9.6
Squatter	0.4	0.5	0.3
Other	0.3	0.3	0.3
Total	100.0	100.1[7]	100.0

b. DWELLINGS CLASSIFIED BY TYPE

Type of Dwelling	Number (to nearest thousand)	Percent
Separate house	328,000	78.0
Flat/Apartment	67,000	16.0
Barracks	3,000	0.7
Out-Room	4,000	1.0
Part of Commercial Building	12,000	2.8
Other Private	4,000	1.0
Other	2,000	0.5
Total Dwellings	420,000	100.0

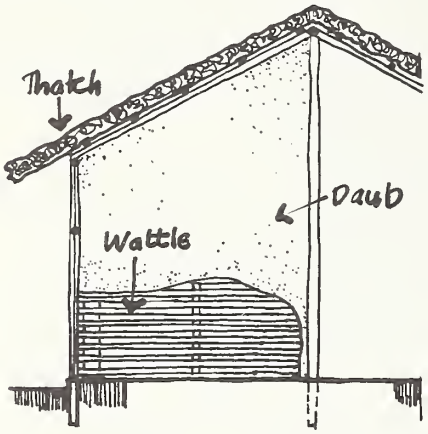
c. PERCENTAGE DISTRIBUTION OF DWELLINGS BY NUMBER OF ROOMS

No. of Rooms	Total	Urban	Rural
1	32.7	42.3	24.9
2	26.3	19.6	31.7
3	16.1	11.7	19.7
4	8.5	7.5	9.3
5	5.3	5.9	4.9
6	2.8	3.3	2.4
7	2.6	3.4	1.9
8 or more	5.8	6.3	5.3
Total	100.1[7]	100.0	100.1[7]

[6]See reference 1.
[7]Sum total exceeds 100 percent due to rounding error.

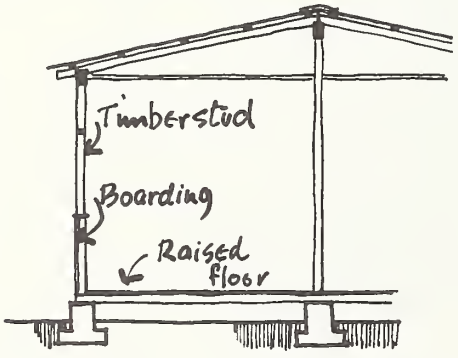
The most popular material among all income groups is hollow concrete block masonry. Physically, low cost housing in Jamaica falls into six types (see reference 1):

Wattle and daub: Until the 1930's rural owners built most low-cost houses in this fashion. The framework of wooden posts and beams, with sticks interwoven horizontally between the posts, was the wattle. This was daubed inside and out with mud from available clay, to create solid walls. The roofs were pitched and made of a thatch made from bundles of dried leaves and tied in place.

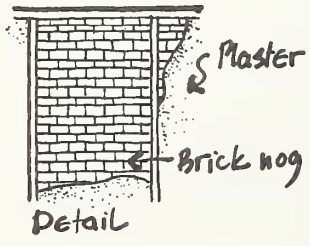


Traditional low-cost houses

Timber stud and horizontal boarding: Roofs are pitched, made of timber rafters covered with corrugated iron sheets or wooden shingles.

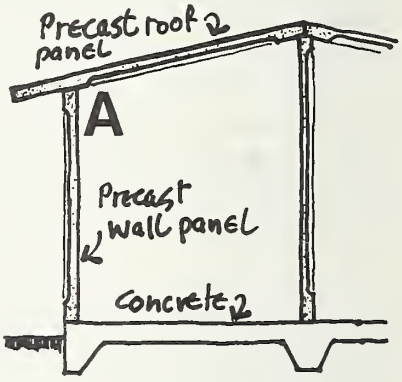


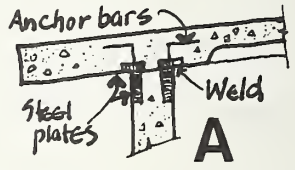
Brick or concrete nog: Wood studs receive a brick or concrete infill or *nog* and are covered with a lime or cement plaster. Houses are usually raised two or three feet above ground.



Hollow concrete masonry: Concrete blocks are manufactured locally: cavities are filled with concrete during construction, and steel bars are added to reinforce against wind and earthquake. Poured in-place reinforced concrete stiffener columns should be included in panels over 4.9 m (16 ft) long, but are often omitted in low-cost housing. Reinforced concrete belt beams are used to cap walls at roof levels.

Large-panel precast-concrete systems: Single panels can extend to the full length and height of a unit. Wall and roof panels are lifted by crane and connected by welding at matching steel inserts. (These systems are not strictly speaking *low-cost* but could be if one steps up volume of production and accepts a lower standard of finishes).





Small-unit precast concrete systems: Precast concrete posts are combined with precast concrete or timber beams, with an infill of concrete panels known as *boards.*

Remaining housing is constructed of brick or stone.

3.2.3 Housing Programs

Except for the 20 percent of needed units supplied or aided by the government there is presently no machinery for providing housing for the very bottom of the income scale. The mechanism used with regard to the poorest citizens is either the continuing growth of shanty towns or the increased subdivision of existing houses to accommodate new households.

In addition, the government now has underway a sites and services project designed to bring housing, essential community services and job opportunities to Jamaica's lower income groups. The project is financed jointly by the Government of Jamaica and the

International Bank for Reconstruction and Development (IBRD). A special unit has been created to carry out the project, which should demonstrate a more practical and desirable alternative to existing low-cost housing programs in Jamaica. This is so because the project has been designed on the basis of what low-income households can afford. Together with training and technical assistance, the project is expected to lead to institutional reforms that will provide the management for long-term housing programs.

Families with an annual income of less than $1,650 (1974 U.S. dollar equivalent) are eligible (see reference 1). The goal is to provide 6,000 serviced lots in the next three years. Lots are to be available in three options: with connections for electricity, water-supply and sewerage, plus *materials* for a toilet-kitchen-shower core unit; the same, but with a *built* core unit, plus *materials* for shelter and enclosure for the rest of the house; and the same as the preceding, but with the core-unit and shelter built, and *materials* only provided for enclosure of the rest of the house. Serviced lots are to be occupied on a leasehold basis, and loans for materials will be provided through credit unions.

The project will also provide related utilities, known as infrastructure, and community facilities: primary school, day-care centers/basic schools, health centers, community centers, trade schools, police posts and market sheds. Industrial financing for small to medium-scale industries (e.g., garments, leather goods, ceramics, toys) will create additional employment at a low-cost per job ratio; the required supporting consulting services will be provided.

Although the main focus of the Jamaican government is on *sites and services*, there are other government programs. These consist of a mix of government-built housing for sale or lease (1970-1975 goal: 3,125 units); owner-occupied government subsidized units (3,600 units); rural housing projects (4,880 units); indigent housing built on land owned by recipient (2,250 units); urban renewal projects focused on Kingston (4,876 units); plus assistance furnished to housing cooperatives (see reference 1).

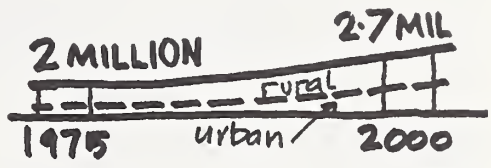
3.2.4 Wind Patterns

Records made between 1886 and 1967 show that the paths of 19 hurricanes and tropical storms passed directly over Jamaica and those of 98 (48 of them having hurricane force winds) passed within 240 km (150 miles) of the island (see reference 1).

Despite the frequency of hurricanes in the Caribbean, direct hits on Jamaica are clearly few when compared with the number of near misses. Near misses are often accompanied by flood rains which cause much damage.

3.2.5 Population Trends

Table 3 shows the results for Jamaica of a world-wide survey conducted by the United Nations to identify population trends. The information is updated through June 1974. Population figures are broken down by urban and rural, and indicate projected rates of increase. Figures for periods from 1975 to 2000 are given. The trend shows increased urbanization along with a net decline of population in rural areas.



Total population will rise slightly. Rural population will actually decline

3.3 BANGLADESH

3.3.1 Socio-Economic Aspects

Bangladesh is a nation with one of the highest population densities and fastest growing populations in the world (see table 3). The country is faced with various problems:

- Steady population growth has forced families to live on land that is increasingly substandard and subject to wind-induced flooding.
- Periodic flooding of low-lying land further increases density—from about 525 persons per km^2 (1360 per mi^2) to a temporary 15,400 persons per km^2 (40,000 per mi^2) in coastal storm regions, as families flee to land left dry.
- The partition of India and East Pakistan (now Bangladesh) in 1947 left the higher land, with its supply of solid construction materials such as stone and timber, on the Indian side of the boundary, while the Bangali population on the treeless alluvial plain was left with few resources for protection.
- The industrial output accounts for only nine percent of the gross domestic product (mostly jute processing) (see reference 5).
- The average number of rooms in 1960 per household was 1.8. Fifty-three precent of householders lived in single room dwellings, and the

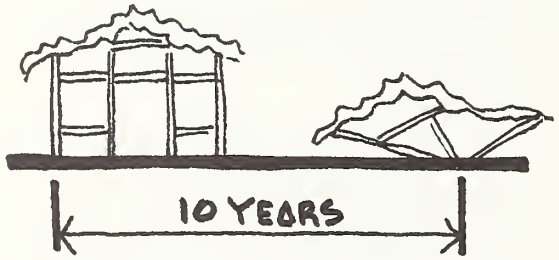
average density of occupancy was 3.2 persons per room. In the case of 31 percent of the population, five persons or more share a room. Clearly, any damage from intense windstorms risks major casualties to a population as densely crowded as this.

Ninety-two percent of the population is rural. The rural population lives in the patriarchal family compound. When sons marry, a new room is erected for the new household on the same field as the parents, next to the parents' house. Thus, houses occupied by families that are paternally related are grouped together. These clusters provide shelter to families numbering as many as 40 members; even higher figures are common. Houses are usually surrounded by dense trees and other tropical vegetation.

Rural housing as part of the agricultural system: Bangali villagers view housing as part of their agricultural system, rather than as a building discipline as in the West. Thus, house building and repair is seasonal, like other farm activities. It helps relieve unemployment. Villagers will grow building materials for houses on their own land. A tree, for example, will serve as a fruitbearer, windbreaker and fuel, until needed as a building material.

Similarly, a man's jute and the earth itself serve him both for agriculture and for building.

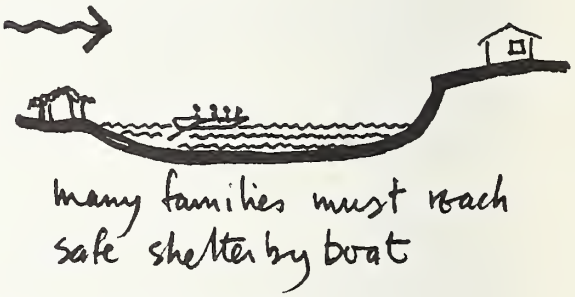
Due to the climate, the bamboo *kutcha* house (described later) itself decays over a 10-year cycle, if not destroyed by a storm before then.



Responses to disaster: A report prepared after the disastrous November 1970 cyclone reveals an interesting set of attitudes. Fifty-seven families of various economic levels in the community of Galachipa were surveyed. Dr. Aminul Islam who collected information after the May 1965 and November 1970 storms, found that:

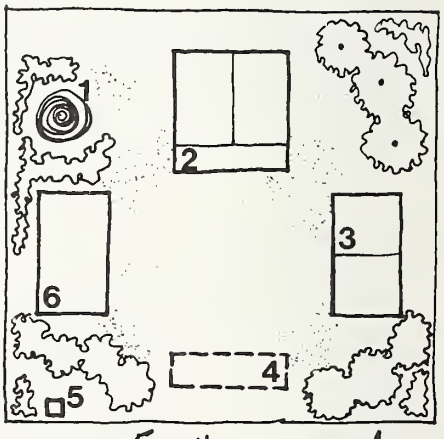
- After 1965 no family wanted to move, though many families rebuilt their houses using higher plinths and stronger posts
- After 1970 only five families wanted to move; 56 still lived on the site of their old home
- Thirty-eight families were still living more than 1.5 km (0.9 mi) from a *pucca* (well-built) structure that could shelter them in a storm
- Fourteen were still living 5 km (3 mi) from a pucca structure
- Nineteen families still needed a boat to reach a pucca structure
- Not even half the families would spend their money first on housing. The others' priorities were food and cattle.

The majority said that if they had the money for housing, they would build one small pucca house, rather than several kutchas (or low quality houses) or corrugated iron (CI) houses. In general terms, the survey found the families fatalistic and pessimistic over protection measures.



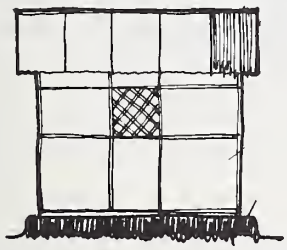
3.3.2 Housing Patterns

The rural population is divided into land owners and landless laborers. One out of five villagers is landless. The average land owning villager has 0.6 ha (1.5 acres) and usually rents another acre from well-to-do villagers. Houses tend to be scattered throughout the village.

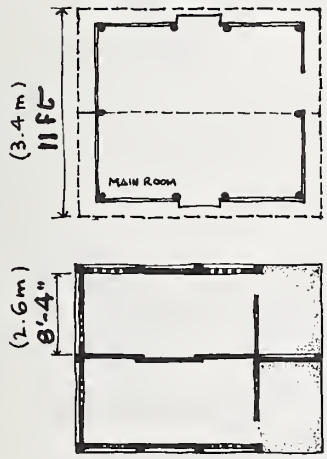


Rural houses are known as "kutcha" or raw structures, with a plinth made of mud, and walls and roofs of bamboo, straw and leaves. These houses need to be maintained constantly and seldom provide safe shelter against rain and wind. Ninety percent of rural houses are built this way. Only about one in a hundred has walls of concrete, baked brick or stone. About one house in three has roofing made of corrugated galvanized iron or asbestos cement.

As 72 percent of the urban population cannot afford to pay rent for even the cheapest housing, they live largely in flimsy shacks, mostly in squatter settlements. This housing is made of bamboo, often consisting of a piece of woven split bamboo fencing bent in the shape of a semi-circle. Headroom is low and occupants spend most of their time outdoors. Even moderate winds blow these houses away despite efforts to hold them down by putting counterweights on roofs.



Typical rural house with bamboo posts, fencing and corrugated iron roof.



Typical low-cost house with brick walls

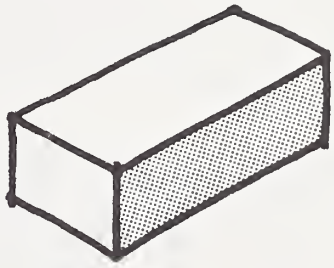
The stronger urban houses usually have burnt clay brick walls, with flat reinforced concrete roofs. Since the walls are usually 0.25 m (10 in) thick, gravity tends to preclude failure through wind stresses. Failures are due largely to substandard mortar or poor workmanship.

What happens to the houses: In the 1970 storm, it was the wind that caused initial housing destruction; the storm surge accounted for people and animal casualties. Here is how the materials fared:

Material	Condition
Thatch	Destroyed or lost
Bamboo matting	Usually destroyed or lost
Wood or bamboo supports	Broken, recovered, reusable
CI sheets	Damaged, in part reusable
0.13 m (5 in) brick	Destroyed. If preserved hard to reuse
0.25 m (10 in) brick	Intact if concrete roof

Middle and upper income rural families use CI sheet and wood. These resist wind and water if well-built. If not, owners can retrieve materials and rebuild unless the materials are scattered by flood waters. However, partial losses after a storm often cost more to make up than would a total rebuilding of the less permanent kutcha house.

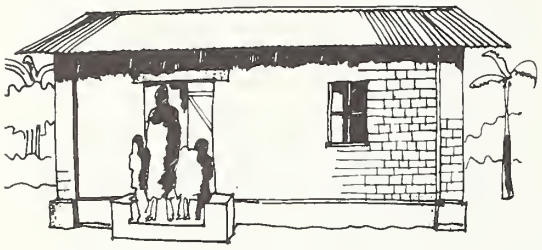
Other types of housing and housing materials: CARE, Inc. type buildings (named after the U.S. relief organization) use soil cement blocks and corrugated iron sheets for roofs. Blocks roughly the size of a U.S. concrete block are made in a simple-to-use machine which compreses a mixture of about 90 percent non-saline soil and 10 percent cement to make about 300



Hand-pressed blocks are made of soil and 10% to 12% cement. Corrugated iron roof sheets are anchored to walls with tie-rods

blocks a day. A typical house requires approximately 1200 blocks. A minimum of skilled labor is needed to construct this kind of house, which is very popular in the country. The key to roof wind safety is to properly anchor the roof to the block walls.

CARE, Inc. has also developed a new composite building material, made of pulp from the core of the jute plant, jute cloth and a plastic resin for binder and facing. This seeks to combine a locally plentiful material (jute) with synthetic binders which can be manufacturered into panels by domestic industry.

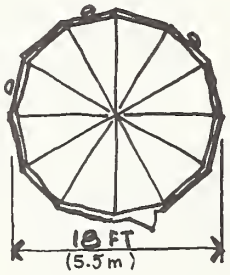


Simple machine makes blocks made from soil and cement

Several variations of material and configuration have been formulated for laboratory testing, prototype construction and wind testing of full-scale units. Four prototypes have been developed so far. These are:

- A pie-shaped, domed structure made of a 19 mm (3/4 in) compressed jute-waste board faced with polyester resin and glass. Public reaction was good until the facing was identified as plastic, for plastic was identified in the public mind with a brand of cheap and brittle crockery. Those who acknowledged the strength of the plastic nevertheless faulted the house for its roundish dome-like shape. This made partitioning difficult and made it unsuitable for low-income families—especially the 80 percent Muslim families with their tradition of isolating women in one part of the house.

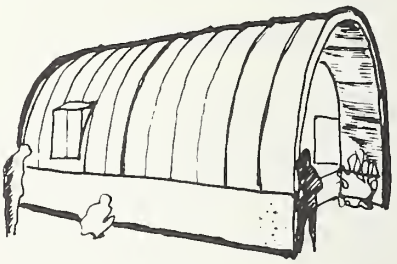
Pie-shaped CARE house (Prototype 1) was sturdy, but shape caused some problems



- A self-supporting house, rectangular in plan and with an elliptical roof profile, with curved panels made of the same combination of synthetic resin and jute. No component was to weigh more than 45.4 kg (100 lbs), so it could be easily managed by two men. It was designed to resemble traditional house shapes.

CARE Prototype 2 has small, light components, is more traditional shape

- A structure using the above materials but geared for use in larger, non-residential buildings.



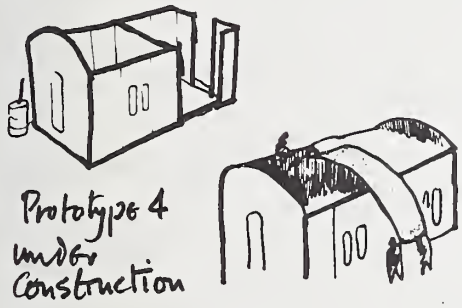
- A structure designed to substitute the jute/plastic material for the traditional thatch or corrugated metal roof and its customary wood or bamboo support rafters. The new roof of this prototype was designed to fit over either traditional or new walls.

Prototype 4 is designed to be used with more of traditional elements

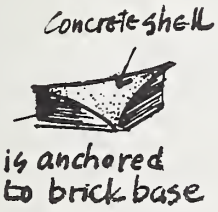
These four prototypes can be anchored directly to the soil or to standard perimeter footing foundations. Many of these prototypes have been used for other than residential purposes, and as such have been very

popular. These uses have included a medical operating theater, dispensary and office. From a socio-economic view, this is seen as a useful lesson, in that citizens of Bangladesh can get to know the structures in a service role without having to accept them suddenly into their personal lives as homes.

Two additional CARE, Inc. prototypes of more traditional appearance were developed in the United States using a panel made of a jute reinforced polyester core and a fiber-glass reinforced polyester facing. The three by six m (10 ft by 20 ft) two room units successfully passed severe simulated wind and water tests.



Reinforced concrete shell roofs of hyperbolic paraboloid shape have been used for industrial and suburban housing. The roof is anchored to the supporting brick walls by means of 13 mm (1/2 in) mild steel bars at the corners.



One related project funded by AID's Office of Science and Technology in Bangladesh contains several innovative ideas and offers a number of lessons in socio-economic planning (see reference 4). The project was carried out by a Carnegie Mellon University team headed by Charles H. Goodspeed and Volker H. Hartkopf. During 1974 and 1975 the team—which included architects, engineers, planners and sociologists—developed a prototype, very low-cost (goal: $10 per person per shelter) housing unit for use in a variety of relief and rural development situations in Bangladesh.

The prototype had to be locally acceptable, and subject both to easy upgrading or to a reduction back to its basic materials.

The result was an *A*-frame modular housing system which was able to use a wide variety of local, indigenous materials. The structure was cheap, labor intensive, easily erected and reportedly resists wind and floods. The advantage from a wind resistance standpoint is the inherent strength and stability of the *A*-frame. The structure, with its thatch roof and an ingenious venting detail, appeared to offer some pressure equalization to reduce the effects of high winds exerting strong interior upward pressures on the roof. It was not evident from the project's report how the bamboo framing members were to be anchored in the soil to prevent overturning of the structure in high winds.

From the viewpoint of cultural acceptance, Dr. Vijai Singh, a sociologist on the team, reported a good deal of opposition to the test unit, both among the Bangalis and Biharis. The shape was not common in the area (some residents commented that they looked like "Christian churches", though these feelings might have been influenced by their understanding that these projects are financed by Westerners, and it was "too tall." Residents said that continuous reduction of space from ground to roof due to the *A*-frame was rare in traditional Bangali architecture. The popular rural housing structures have four walls on the ground despite variations in roofing patterns. Most of the brick houses have flat roofs and others are raised in the middle. Dr. Singh felt the structures could be made more acceptable by lowering their height and changing them in appearance to conform to the traditional structures.

All the respondents complained about the tightness of space inside the structures and felt they had been built without due concern for the needs of the families living in them. Most complaints centered on lack of storage and kitchen space. Also, residents in some areas felt the windows were too high, and should be lowered so some air could flow at floor level. It was difficult to sleep inside in hot and humid weather. Several different door styles were tried, but none proved popular and all residents suggest a bigger entrance and a door that could be shut and locked.

The original structures appear to be a version that will withstand high wind, but they have yet to be formally tested in a high wind situation, so that their performance under such conditions is still largely unknown.

3.3.3 Housing Programs

The 1971 war of independence left about two million families homeless. Sizeable housing rehabilitation and reconstruction efforts are now under way in rural areas.

The Delta Housing Program: Beginning in 1972, a rural cooperative housing scheme got under way in the Delta area, a coastal strip of 10,400 km^2 (4000 mi^2) with 4,270,000 inhabitants. The program's main features

have been:

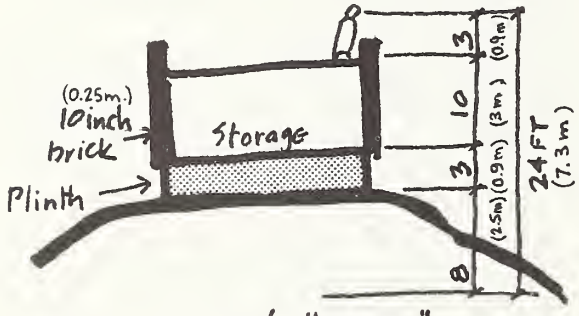
- Erection of 7500 - 3 by 6m (10 by 20 ft) soil-cement-block houses on burnt-brick foundations to withstand severe flooding and substantial cyclonic winds.
- A cooperative plan under which farmers and fishermen undertake to repay 50 percent of the cost of the house out of agricultural income to their local cooperative society. These societies are linked into a complex cooperative system known as the Integrated Rural Development Program. (The other 50 percent of cost is subsidized).
- To reduce the villager's concern about the annual fate of his house, and thus show the villager how to attend more to long range agricultural planning and development; and, further, to reduce the villager's (and the government's) repair expenditures after every cyclone season.

Siting: Creation of either artificial barriers or embankments in low-lying areas (so as to either shield houses or raise them above mean high flood levels) has been proposed as part of any new wind and flood protection program.

It was found, for example, that Dutch *polder* type barriers have protected many houses in recent storms. Even when the water breached the barriers and caused flooding, it did not destroy the houses.

By and large, raised embankments or platforms are thought a better approach. Its main features are:

- Construction of a platform 2.4 m (8 ft) above mean high tide level. Over it, erect a small 5.5 m^2 (60 ft^2) *pucca* quality shelter house of 0.25 m (10 in) brick with a flat roof (behind a parapet) 4 m (13 ft) above this platform includes a 0.9 m (3 ft) plinth. A man, woman or child standing on such a roof platform would be at least 7.3 m (24 ft) above mean high tide level; this is said to be protection against even the worst onslaught of a storm surge.



Semi-private "pucca" shelter is raised above storm surge level

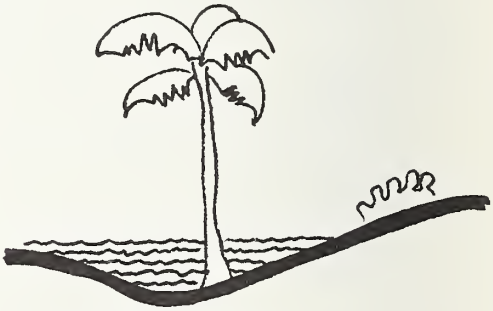
- Assignment of responsibility to each *bari* or community for building and maintaining such a shelter, the interior of which could serve as storage.

Nucleus housing: Widening the concept of *nucleus* housing has been proposed. Under this concept, a basic, small wind-secure house (such as the soil-cement CARE, Inc. house) serves as a starting point for adding space horizontally or vertically to the taste of the owner or tenant. Open, bamboo-and-thatch lean-to additions have been created in some localities. In others, soil-cement blocks have been plastered to better resist wind, floods and temperature extremes. Occasionally, a second and even a third story are added.

Wind secure house with individualized lean-to

Materials: Since villagers are inclined by their socio-economic priorities to put food and cattle ownership before housing, a plan is proposed to ensure building materials delivery. Its main features are:

- Government subsidies should be in the form of *materials* not *funds*.
- The goverment should set up local technical assistance units which would help with organized harvesting of wood; introduce mechanized milling to ensure tighter fit; show how to cultivate plants that are sources of building materials (such as the Nipa palm which is semi-aquatic and does not displace food growing and grazing land); and provide seedlings.



Nipa palm is semi-aquatic. It does not displace food growing land and can be made into a building material

- Clay is plentiful in Bangladesh, and there is a 1000-year old tradition of burnt brick construction. Crushed, these bricks can replace the imported cement in concrete. It is useful as a foundation and, in enough thickness, 0.25 m (10 in) to better resists extreme winds.
- The making and use of cement-soil block. (This topic has been discussed elsewhere in this report.)

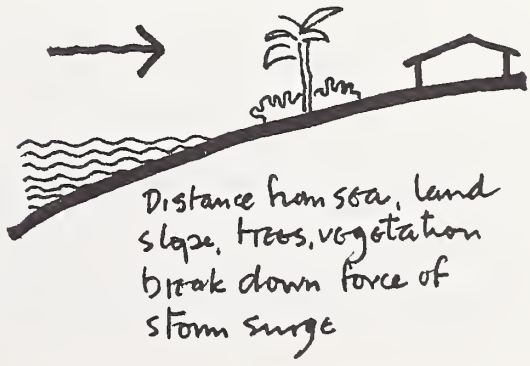
3.3.4 Wind and Flood Patterns

The most common sources of wind in Bangladesh are the cyclonic typhoons, tornadoes and norwesters. Damage is not only from wind pressures but from high walls of water known as storm surges. Thus, the cyclone of November 12, 1970 caused storm surges some 7.6 m (25 ft) high; nearly 100 percent of the kutchas and semi-permanent houses were demolished in the area of the storm. The coastal areas of the country are the most vulnerable to cyclonic storms.

Tornadoes are the most destructive storms. They usually happen on land during the warm season in flat areas, with few natural barriers to hinder them. Eighty-nine m/s (200 mph) winds are common, but maximum wind speeds up to 223 m/s (500 mph) have been estimated by some experts.

Storm surge: The storm surge that accompanies cyclones in coastal Bangladesh usually moves inland at about storm speed 2.2 to 11 m/s (5 to 25 mph). Its mean depth over a particular site is determined by five variables, the last two of which can to some extent be influenced by man.

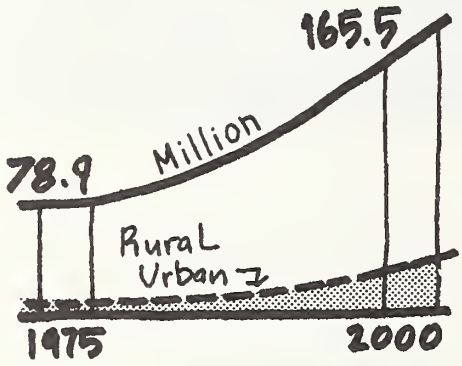
1. Severity of storm (this determines height of water over normal sea level).
2. Level of daily sea tide at time storm strikes.
3. Land configuration and wind direction (these reinforce or impede rise of water).
4. Elevation of site (natural plus build-up).
5. Distance from sea or major inlet (land, trees and other vegetation resist flow).



Storm warning systems: The huge death rate of the November 1970 cyclone was due in part to the use of a new warning system unfamiliar to the coastal villagers.Since then, the new *danger—great danger* warning scale has been supplemented with a preparedness system under which 10 volunteers per *bari*, each equipped with signals, lights, etc., are linked by radio to Red Cross central headquarters in Dacca, which receives and disseminates the latest storm information. There are also specially trained local relief teams.

3.3.5 Population Trends

Table 3 shows the results for Bangladesh of a worldwide survey conducted by the United Nations in an effort to identify shifting population patterns. The information is updated through June 1974. Population figures are broken down by urban and rural, and indicate rates of increase. Figures for periods from 1975 to 2000 are given. Population will more than double in a single generation, with the rate of increase of urban areas expected to be over double that of rural areas.



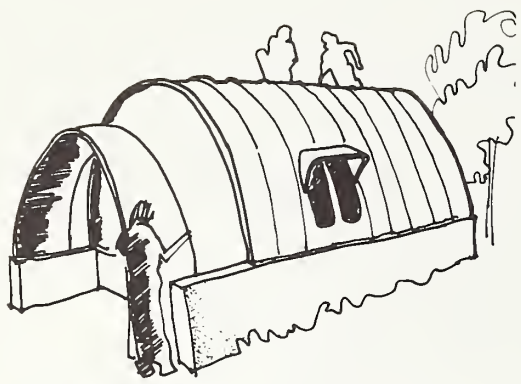
Population will more than double in one generation

Facing Page: Sites-and-services concept may provide land, core walls and basic utilities. Families add rooms according to their means.

4.0 CONCLUSIONS

A clearcut picture of problems, needs and solutions emerges from the diverse research reports, surveys and statistics that served as a basis for this report:

- As to the socio-economic aspects of designing wind-resistant low-rise/low-cost housing, the cultural characteristics and financial capacity of low-income groups must be taken into account along with the technical criteria if sound solutions are to stand the test of widespread acceptance. This does not mean that new, stronger and less costly materials and construction techniques must blindly imitate traditional forms and processes. Nor, on the other hand, should these ignore the long traditions of indigenous building in the three countries discussed in this report.
- One emerging result of new low-cost housing tests in Bangladesh bears watching. The interim use of new prototypes for other than residential use, in a highly visible way as clinics and community offices, points up a viable way of exposing new forms and materials to prospective users before they must take the big cultural step and live in them as families.



Highly visible use as non-home helps pave way for acceptance

- Similarly, the so-called *sites and services* approach, if tailored closely to the characteristics and outlooks of the communities involved, can capitalize on the proven initiative, ingenuity and hardiness of squatter and similar families. This will help overcome the chronic barriers of insufficient financial and material resources in developing countries.
- Closely allied with the thinking behind *sites and services* is the wisdom of gearing innovations in materials or method to the relatively plentiful labor supply in most developing countries.
- Emphasis on use of local labor does not preclude prefabrication, but places new focus on the need to identify, produce, adapt or combine cheap local substances made from natural earth, trees and plants. Bamboo, various kinds of soil, as well as jute, hemp, cane, split trees, straw, peanut shells and coconut husks are among materials that have been combined with manufactured substances such as cement, plastics and metals to produce inexpensive, sturdy building materials.
- How the building blocks are assembled is one of the major touchstones for stable, wind and water damage resistant houses. The chief caveats are adequate anchorage of roofing materials and trusses (if any) to walls. Structural design of roof members, splices and joints must accommodate high wind velocities. Anchorage of houses to the ground must be designed to prevent over-turning; and wall openings must be placed to avoid weakening the structure at vital points and to prevent wind from entering and exerting interior upward pressure on the roof. Similarly, design features such as roof pitch and overhangs must observe latest findings on positive and negative wind pressure distribution.
- Proper placement of houses in groups as well as to accommodate prevailing wind direction and land features will always raise the wind damage resistance of houses. This should be one of the first criteria to observe when planning houses in areas subject to extreme wind.

APPENDIX-REFERENCES

(1) Adams, A. D., "Low-Cost Housing and Extreme Wind-Related Problems in Jamaica," (Published as part of U.S. National Bureau of Standards Interagency Report NBSIR 74-567), (Washington, D.C.: National Bureau of Standards, 1973). Available from NTIS, COM 74-11631.

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